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QUARTERLY PROGRESS REPORT NUMBER 2, 1 APRIL - 30 JUNE 1970.(U)

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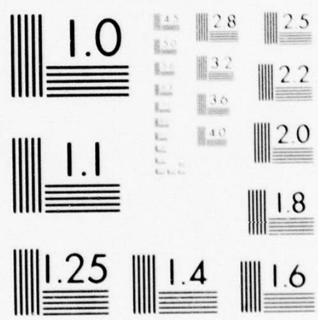
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APPLIED RESEARCH LABORATORIES

THE UNIVERSITY OF TEXAS AT AUSTIN

3 August 1970

Copy No. 1

QUARTERLY PROGRESS REPORT NO. 2
UNDER CONTRACT N00024-70-C-1117
1 April - 30 June 1970

NAVAL SHIP SYSTEMS COMMAND
Contract N00024-70-C-1117
Proj. Ser. No. SF 1990301, Task 01467

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UNDER CONTRACT N00024-70-C-1117
1 April - 30 June 1970.

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I. INTRODUCTION

Applied Research Laboratories (ARL) was awarded Contract N00024-70-C-1117, effective 1 January 1970. Work under this contract is concerned primarily with the test and evaluation of sonar transducers and systems. The transducer oriented work represents a continuation of a portion of the work under a previous contract, Contract N00024-69-C-1066. Another area of work concerns monitoring the development of the AUTEC Sonar Range (ASR); this work represents a continuation of Contract N00140-69-C-0278.

Current progress on the various projects under the subject contract is described in the following chapters. A list of personnel currently working under this contract is included in Appendix B.

II. SUBCONTRACT TO STANFORD RESEARCH INSTITUTE

A. Introduction

To assist ARL with many of the tasks assigned under Contract N00024-70-C-1117, a subcontract was awarded to Stanford Research Institute (SRI), effective 1 March 1970. This subcontract, designated ARL-SC-70-01, requires quarterly progress reports. These reports will be distributed with ARL's quarterly progress reports and will be relied upon to report progress on projects handled primarily by SRI. Joint projects, in which ARL has played a direct role, will be reported upon in ARL's quarterly progress reports (QPR's).

During the first quarter year of ARL-SC-70-01, SRI worked on several projects, which are described in SRI's Quarterly Progress Report No. 1 under Subcontract ARL-SC-70-01. These projects will be described very briefly in Section B.

B. SRI Projects

1. SRI reviewed and commented upon a proposed AN/SQS-26BX transducer repair procedure. This resulted in SRI's preparation of a more detailed proposed repair procedure, which was forwarded to NAVSHIPS by ARL letter Serial E-26, dated 23 March 1970.

2. SRI participated with personnel from NUSL and NUC in the preparation of a questionnaire that was distributed to all shipyards in search of information regarding transducer service life.

3. SRI visited Sangamo Electric Company, Springfield, Illinois, in late May 1970 at the request of NAVSHIPS OOV3C to investigate production tests used on the new TR-237/238 transducers.

4. SRI has continued to participate with ARL in the survey of the WESTPAC activities at which transducers are installed. (See details in Section III.)

5. SRI participated in the STEP Working Group meeting at NUSL during the period 19-21 May 1970 and has continued to participate in various small projects in support of the STEP Working Group.

6. SRI has continued to maintain close liaison with the Mare Island TRF in its role as the STEP Working Group's coordinator.

III. STEP BARGE FACILITY OPERATIONS

A. AN/SQS-31 Sonar Dome Study

Early in the quarter, measurements were completed on the AN/SQS-31 TR-185A transducer mounted in the 100 in. sonar dome. The concluding tests were made with the used dome which had been dented purposely. The dent was later patched with DEVCON F, an aluminum-loaded epoxy compound. No appreciable effect on beam patterns were noted due to the dome or due to the patch.

All measurements in ARL's evaluation of the TR-185A transducer (Ser A-8) and the dome study were incorporated into a technical report (ARL-TR-70-26) entitled "Evaluation of the AN/SQS-31 TR-185A Transducer (Ser A-8) and Experimental Study of AN/SQS-31 Sonar Dome Effects." This report was issued on 3 June 1970.

B. Evaluation of the C-Tech Electronic Scanner

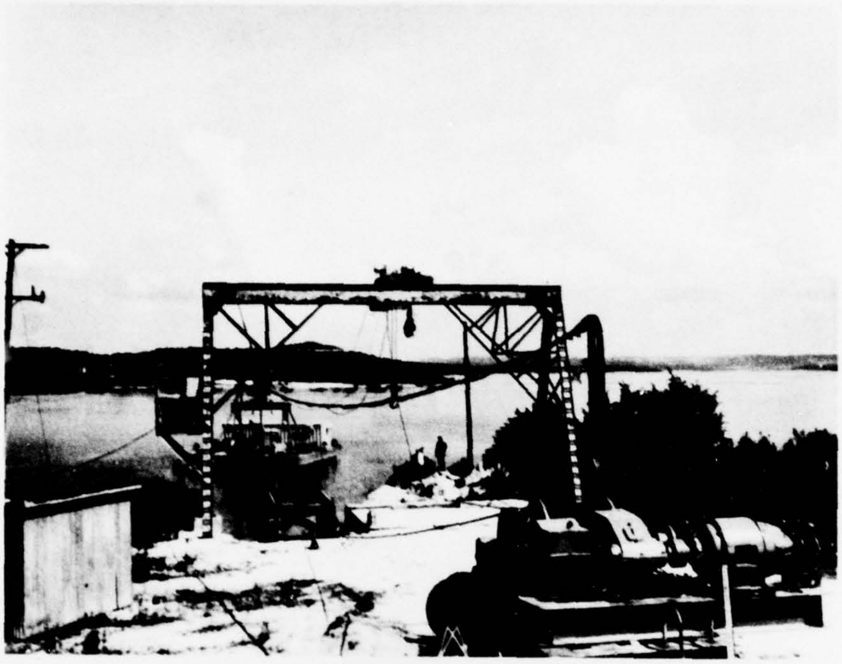
As stated in QPR No. 1, ARL had completed all measurements on the C-Tech electronic scanner and the technical memorandum documenting these tests lacks only printing and binding. This technical memorandum (ARL-TM-70-6) entitled "Side-By-Side Comparison of C-Tech, Ltd., Electronic Scanner with the AN/SQS-31 Mechanical Scanners, Part I and Part II" was dated 1 April 1970. It was completed and distributed early in April 1970.

C. AN/SQS-43 TR-194 Transducer Tests

The AN/SQS-43 TR-194 transducer (Ser A-8) was tested aboard the STEP barge at the Lake Travis Test Station (LTTS) during May and June 1970. This 8 kHz variable depth sonar transducer was subjected to extensive baseline measurements, which included the tests currently prescribed for use by the TRF's in NAVSHIPS 0967-303-9810/9811/9812. A full description of ARL's tests and all test results will be incorporated into a technical memorandum. Writing of this memorandum and data reduction were in process as of 30 June 1970.

D. Study of the Performance of AN/SQS-31 and AN/WQC-2 Transducers Mounted in a Single 185 in. Sonar Dome

ARL was requested by NAVSHIPS OOV3C to undertake a series of measurements aboard the STEP barge to determine the transducer performance of the AN/SQS-31 TR-185A and the AN/WQC-2 TR-232 and TR-233 with all three of these transducers mounted simultaneously in a single 185 in. sonar dome. This transducer configuration is scheduled for use in two installations aboard submarine rescue vessels (ASR Class). A 185 in. sonar dome was received at ARL on 4 May 1970 and both AN/WQC-2 transducers were received on 15 May 1970. Mechanical preparations for these measurements involved the construction of a ring for mounting the TR-185A transducer in the 185 in. dome and a bracket for mounting the WQC-2 transducers. On 30 June 1970, the 185 in. dome was loaded aboard the STEP barge with the newly completed marine railway. (See Figs. 1 and 2.) Testing of the performance of these units was to begin very early in July. Prior to these tests, the individual performance of the WQC-2 transducers had been measured for control purposes aboard ARL's general calibration barge.

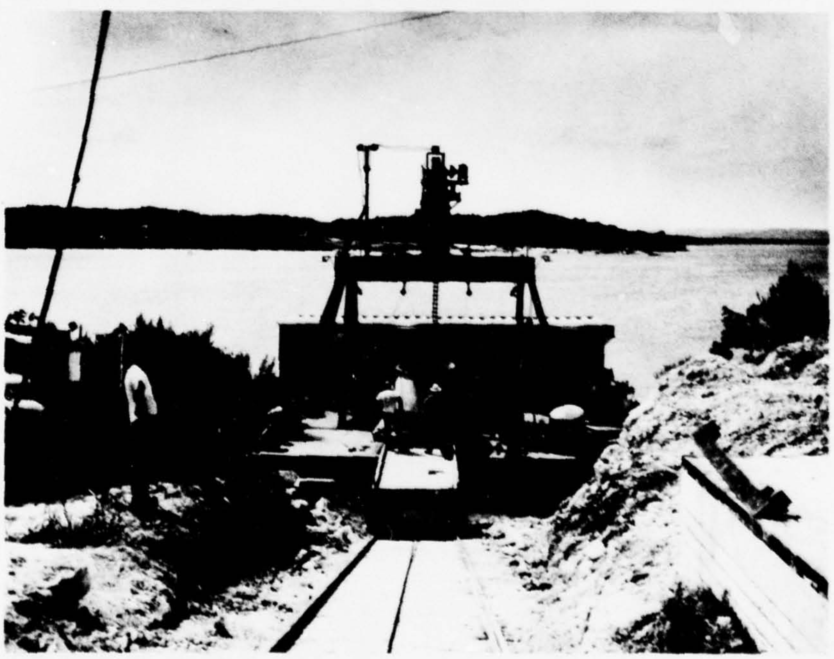


(a)

(b)

FIGURE 1
STEP BARGE FACILITY AND MARINE RAILWAY

(a)



(b)

FIGURE 2
MARINE RAILWAY DURING DOME LOADING OPERATION

E. Construction of Marine Railway for Loading Transducers Aboard the STEP Barge

During this quarter year, ARL's marine railway was completed and was used initially on 30 June 1970 for loading the 185 in. sonar dome aboard the STEP barge. The winch that propels the rail car was completed and installed on its pedestal on 11 June 1970. On the same date, the 10-ton lifting mechanism on the traveling hoist was made operational. Following the completion of the electrical distribution system on 16 June, the rail car was installed on its track and the winch and emergency brake system tested successfully (17 June 1970). Figure 1(a) shows a view of the marine railway as of 22 June 1970. The main propulsion winch is shown in the right foreground; the rail car can be seen at the head of the track. The traveling hoist has two lifting capabilities. The hook shown is the 10-ton capability that was operational. The 30-ton hook was one of the few items of the entire facility not operational as of 30 June 1970.

Figure 1(b) and the two photographs in Fig. 2 show some of the operations that occurred on 30 June 1970 when the 185 in. dome was loaded aboard the barge. Figure 1(b) shows the rail car being drawn up the slope after the transfer car had been loaded from the STEP barge to the rail car. It can be seen that the STEP barge had been "driven" to the shore for this operation. The sonar dome can be seen aboard the large truck backed into position on the concrete slab beneath the 10-ton hoist.

Figure 2(a) shows the rail car with the dome aboard just prior to transfer of the transfer car and the dome aboard the STEP barge. Figure 2(b) shows a view from the head of the railway of the STEP barge just after transfer of the load. The empty rail car can be seen at the foot of the track.

The next phase of construction regarding the marine railway will be the laying of more track. It is likely that the level of Lake Travis will drop well below the present rail track during the summer months. It is anticipated that in August 1970, the track will be extended to the water's edge. After fall and winter rains raise the lake level, the railway will again be operational.

IV. PARTICIPATION IN STEP WORKING GROUP ACTIVITIES

A. Attendance at STEP Working Group Meeting

The STEP Working Group met at the Navy Underwater Sound Laboratory (NUSL) on 19-21 May 1970. Messrs. J. E. Stockton and D. D. Baker attended the meeting from ARL. The minutes will be prepared by Mr. H. C. Evans of NAVSHIPS 00V3M.

B. Production of Dummy Loads for Transducer Repair Facilities (TRF's)

ARL completed the printing of a suitable instruction manual for the ARL Type 2 TRF dummy load in early April 1970. Two of the dummy loads were shipped to the Boston TRF, two to the Mare Island TRF, and one to the Pearl Harbor TRF on 3 April 1970.

During the STEP Working Group meeting of 19-21 May 1970, both the Boston and Pearl Harbor TRF's confirmed that their units had been received; Mare Island had not received its units. As of 30 June 1970, the two units shipped to Mare Island have still not been located, although a tracer was issued from ARL. On 5 June 1970, a single Type 2 dummy load was shipped to Mr. E. M. Spurlock of SRI so that it could be handcarried to the Mare Island TRF to be used during the training session given by Scientific-Atlanta. If the freight company is unable to locate the lost units, ARL will furnish Mare Island two additional units.

C. Procurement of Prototype AN/PQM-( ) Portable Sonar Transducer Measurement System

Applied Research Laboratories issued Request-For-Bid No. 29702 to a selected list of bidders on 8 April 1970. Bids were to be received at ARL by 18 May 1970. Effective 4 June 1970, a subcontract designated ARL-SC-70-02 was issued to Ocean Data Equipment Corporation for the prototype of the Portable Sonar Transducer Measurement System. ARL will monitor the contractor's progress closely during the entire six month development period prior to delivery.

D. Remeasurement of Element Impedance of the AN/SQS-23 TR-208A After Six Months Service Aboard the USS VOGELGESANG (DD 862)

ARL remeasured transducer element impedance aboard the USS VOGELGESANG on 23-24 March 1970. At the end of March, data reduction was nearing completion and a technical memorandum was to be prepared as soon as possible. This technical memorandum (ARL-TM-70-12) was dated 8 May 1970 and was entitled "Impedance Measurements on the AN/SQS-23, TR-208A Transducer (Serial BTD-2-69) After Six Months Service Aboard USS VOGELGESANG (DD 862)."

It is planned that the monitoring of transducer performance aboard the USS VOGELGESANG will continue on roughly a six month basis. Inquiries will soon be made on the next availability of the ship for measurements.

E. Survey of Western Pacific Transducer Test Facilities

ARL and SRI jointly prepared a detailed outline of information required from the WESTPAC transducer test facilities, and this information was officially requested by a NAVSHIPS letter dated 19 December 1969. By the end of March 1970, replies had been received from all

four activities contacted--Ship Repair Facilities (SRF's) at Guam, Subic Bay, and Yokosuka and the Ship Repair Department under COMFLEACTS, Sasebo. These replies were received at ARL on 4 May 1970; copies of the technical information were forwarded to SRI soon thereafter.

By NAVSHIPS letter (00V3M; HCE:rh, C-9674, Ser: 06-00V3M) dated 1 May 1970, ARL was requested to review the enclosures and forward a report to NAVSHIPS by 15 June 1970. Due to other priority matters, this deadline was postponed until August 1970 by telephone conversation with Mr. Herman Evans. It is planned that Messrs. E. M. Spurlock of SRI and D. D. Baker of ARL will meet and jointly draft this interim report. It is thought that it will indeed be an interim report, because cursory examination of the information received from the WESTPAC activities reveals that insufficient information is available for preparation of a detailed report such as that prepared after the ARL/SRI survey of the ten naval shipyards. Such a comprehensive technical report was the goal of this WESTPAC survey.

F. AN/FQM-10(V) Improvement Program

It was previously stated that ARL had recommended to NAVSHIPS that the Scientific-Atlanta sampling digital voltmeter be procured for evaluation aboard the STEP barge. It was intended that this unit would be evaluated prior to any recommendation for incorporation of the sampling digital voltmeter into the AN/FQM-10(V) systems. Such a unit is being procured for ARL through NUSL and was scheduled for delivery on 30 June 1970. The unit was not received by that date.

Two of ARL's previous recommendations regarding AN/FQM-10(V) improvements were discussed again with Scientific-Atlanta (S-A)

personnel during the STEP Working Group meeting at NUSL. It is understood that S-A has found a reasonable means of implementing improved protected circuitry on the scanner and this will be accomplished as soon as possible. The other improvement concerned implementation of the PVIM as a pulse phase meter. This matter was to be postponed until further data could be gathered regarding all of the TRF's possible uses for such a phase measuring capability. Questions regarding needs for phase measuring capability were asked of the TRF personnel by S-A during the STEP Working Group meeting.

G. AN/FQM-10(V) Configuration Control

ARL had been asked during the STEP Working Group meeting of November 1969 to act as the configuration control point for the AN/FQM-10(V) systems after Scientific-Atlanta completes the present service contract. This committment was reaffirmed at the May 1970 STEP Working Group meeting. It was stated that ARL would assume this role as of 1 July 1970 and that ARL would be provided one copy of each drawing applicable to any installation of any of the AN/FQM-10(V) systems. It was also stated by Scientific-Atlanta that all documentation would be guaranteed correct as of 30 June 1970. This information has not been received at ARL to date.

Thus, ARL will assume the configuration control assignment with a guaranteed set of accurate documentation. It will then be ARL's responsibility to ensure that any change made to any of the systems will be properly documented at the installation and at ARL. Thus, instantaneous accuracy of all documentation will be maintained. In this same role ARL will be forwarded a complete failure log from each of the TRF coordinators on a regular basis. ARL also will rely upon the coordinators to affirm,on request, that the configuration of the

AN/FQM-10(V) systems has not been altered at any of the TRF installations. It is also anticipated that ARL personnel, as occasions materialize, will critically inspect the FQM-10(V) installations at the TRF's.

H. Study of the "Next Generation" AN/FQM System

ARL is actively pursuing installation of the PDP-8 computer (with digital plotter and digital magnetic recorder) aboard the STEP barge. This small computer was provided to ARL by NAVSHIPS for development of a system for making *in situ* shipboard nearfield measurements and computing farfield acoustical parameters. Support for this nearfield development work waned and ARL has used this computer for various small projects.

The present plan is to install the computer aboard the STEP barge during the summer of 1970. Its presence aboard the barge will serve two functions. As time and priorities permit, the nearfield work will be revived and the computer will be in the correct location to be used. In the meantime, interfacing the computer with the AN/FQM-10(V) will provide many interesting capabilities. It will provide the capability of logging data automatically on magnetic tape and will permit computations to be made simultaneously. For example, as the impedance data are acquired with the PVIM, the computer can calculate real power. In addition to these data processing capabilities, as priorities permit, it will be ARL's intent to experiment with computer control of transducer evaluation measurements. It is hoped that one product of this research will be the formulation of ideas on what might constitute the "next generation" AN/FQM system. That is, the degree of automation that one would desire in such a system for the TRF's could hopefully be determined by experiments aboard the STEP barge.

The work done to date on the installation of the PDP-8 computer aboard the STEP barge includes the building of three hardware items--the interface between the computer and the digital plotter, the interface between the computer and the digital tape recorder, and the interface between the computer and the PVIM. The PVIM will serve a major role as a sensor because of its capabilities to measure amplitude and phase of a pulsed signal. Its output also is digital and relatively simple to input to the computer. The digital plotter is fully operational, and the digital tape recorder interface is currently being debugged. It is estimated that the tape recording system should be operational within a few weeks.

The status of the PVIM interface is as follows. The data transfer buffers were built first and tested by use of a paper tape punch for recording the data. At present, this allows data from the PVIM to be recorded on paper tapes that can later be read into the PDP-8 for analysis and presentation. This capability of recording PVIM data for off-line analysis will serve as an interim interface; it will be used to acquire data prior to completion of a real-time interface between the PVIM and the computer. After this interface is completed, the computer will be installed aboard the barge and will be fully operational.

Equipment racks similar to those of the AN/FQM-10(V) system have been obtained and will be used to package the computer and interface equipment for installation aboard the barge.

V. AUTEC SONAR RANGE (ASR) DESIGN MONITOR EFFORT

A. Participation in Navy/Contractor Conferences

During this report period, ARL has participated in three Navy/Contractor Conferences (N/CC). Since NAVSHIPS personnel were present at these meetings and since minutes of these meetings were prepared by GD/E and forwarded to NAVSHIPS, a detailed discussion of ARL's participation will not be presented in this report. Instead, reference will be made in Sections B and C to particular meetings at which ARL and GD/E exchanged ideas. ARL feels that the close communication engendered by these monthly meetings has contributed significantly to the progress in the development of the AUTEC Sonar Range.

B. Review of GD/E Reports

1. Introduction

During this report period, ARL reviewed and prepared comments on two GD/E reports: 1) GD/E Quarterly Progress Report No. 7, and 2) Receive Beamformer Synthesizer Design Report. GD/E's QPR No. 7 was received at ARL on 22 April 1970. This report was reviewed and comments were prepared. These comments are presented in Section B.2.

The Receive Beamformer Synthesizer Design Report was obtained at the N/CC of 14 May. Comments were prepared and these were handcarried to R. Baline of NUSL at the 17 June N/CC (ARL Memorandum, R. L. Rolleigh to D. A. Smith, dated 15 June 1970).

Since a copy of these comments was presented to NAVSHIPS personnel at that meeting, these comments will not be repeated here.

2. Comments on GD/E QPR No. 7

In general it is felt that QPR No. 7 reflects considerable progress made during the quarter 1 January through 31 March 1970. This report indicates that GD/E has progressed to the point that most of the major problems are recognized and many of them have been resolved. Detailed comments on the report are itemized as follow:

1. On page 18, it is stated that "A complete and thorough investigation of each type of sonar system and class of ship will require additional visits to those particular types of ship." ARL agrees with this statement and strongly feels that one of the major problems in shipboard data acquisition is in the interface between the shipboard subsystem and the ship's sonar under test.

2. A block diagram of the sonar adapter is shown in Fig. 14 on page 33. In this figure only one analog-to-digital converter (ADC) is shown per recorder tape track. This design minimizes the number of ADC's needed and eliminates the need for a digital multiplexer following the ADC. However, for the data recorded on tape to be compatible with the Receive Beamformer Synthesizer (RBS), there must be exactly 12 different hydrophone channels recorded on each recorder channel. Thus, each ADC must sample 12 different signals within one sampling cycle; at the maximum sample rate of 40 kHz, each ADC must perform 480,000 samples/sec. Moreover, these are not sequential samples of the same signal but samples of different signals which may be 180 deg out of phase. Thus, the ADC will have to swing through its entire dynamic range in less than 2 μsec. Also the multiplexer must be allotted some amount of time to switch between widely different

signals and settle before the ADC can begin operation. Because of these considerations, it is felt that a critical design problem exists and that more detailed information should be provided.

3. In Fig. 14 discussed in the preceding paragraph, the analog multiplexer is shown with a maximum of 512 input channels and 22 output channels. Due to constraints placed upon the data format by the RBS, there can be only 12 different signals on each output channel. Thus, as a maximum, only 264 of the input channels can be recorded at one time.

4. On page 34 it is stated that the analog multiplexing and ADC functions are being included in the sonar adapter rather than the recording group to reduce the number of interconnecting cables. It is felt that this approach is an improvement over the previous one.

5. On page 39, paragraph 3.4.2.6, the problem of transmitting power to the vertical array projectors is discussed. It is recommended that impedance matching be used both at shore and underwater. ARL agrees with this recommendation.

6. On pages 40-43, a summary of acoustical tests performed at AUTEC is presented. This summary indicates that those tests were much more comprehensive than was proposed in the Test Model Demonstration, Test Plan and Procedures of 15 December 1969.

C. Research in Areas of Special Interest

During this report period, ARL performed research in four areas of special interest:

1) Vertical Array Signal Conditioner,
2) Hydrophone distribution along the vertical array,
3) Shorebased data reduction, and
4) Sound absorbent coatings.

1. Vertical Array Signal Conditioner

In the previous QPR, ARL discussed the relative capabilities of the "baseline" signal conditioner (with floating-point digitizer) and the signal conditioner presently being developed (with fixed-point digitizer). At the N/CC on 20 March 1970, it was discovered that GD/E recognized that the baseline signal conditioner provided superior capability but that they had abandoned that system because of design difficulties. A work session was set for 14 April 1970 to decide what type of signal conditioner would be used.

In preparation for this work session, ARL continued to investigate possible designs for the floating-point digitizer. At the work session two points of agreement were soon reached: 1) the floating-point digitizer could be implemented and would provide superior data acquisition capabilities, but 2) the fixed-point digitizer would be much easier to implement and would provide enough capability to meet the contractual specifications, although it would demand increased ship's time on the range. The amount of increased time-on-range is an ambiguous quantity that depends primarily on what type of experiments are performed at the ASR. It was generally felt that increased time-on-range would be a favorable trade-off against the added complexity of a floating-point digitizer. Although ARL feels that it would be best to build into the ASR the maximum possible capability, it is true that, in the final analysis, reliability and expense must be weighed against capability. Therefore, the final decision was that the fixed-point digitizer would be used with the condition that the gain setting of the preamplifiers preceding the digitizers could be reset with a minimum delay (about 120 μsec). This decision is documented in the minutes of the 14 April 1970 N/CC.

2. Hydrophone Distribution

In ARL's QPR No. 3 under Contract N00140-69-C-0278, the vertical array mechanical structure was discussed; concern was expressed about the poor acquisition capability at small depression angles. At the N/CC on 19-20 March 1970 GD/E proposed a new design that significantly affected the data acquisition capability of the vertical array. They recommended the use of two hydrophones placed 180 deg apart on each acoustical module (essentially the baseline design). This change increases data acquisition capability and is highly favored by ARL.

However, at the same N/CC GD/E continued to recommend uniform spacing of elements from 230-3400 ft depth. The results of ARL's analysis indicated that this spacing would not provide adequate data acquisition at small depression angles for surface ships, and it was recommended that GD/E reconsider the element spacing from this viewpoint. NUSL was in strong agreement with this suggestion and a work session was planned for 14 April to discuss the distribution of acoustical elements on the vertical array. At the 14 April meeting it was agreed that there should be 15 or 16 acoustical modules on the vertical array with a high uniform density region near the surface and a lower uniform density elsewhere. GD/E would study the data acquisition problem and recommend exact spacing of elements at the 13-14 May N/CC.

Prior to the May meeting, ARL reconsidered the data acquisition problem and arrived at the following conclusion. There should be three different regions on the array, with a different element density in each area. The top portion (0-500 ft depth) should have a high density to provide adequate data acquisition at small depression angles for surface ships. The bottom portion (2000-3400 ft depth) should have a very low density because it is expected that no

data (or very few data) will ever be required from a ship operating below 2000 ft. The middle portion of the array (500-2000 ft) should have a medium density. It is felt that this overall distribution would provide optimum data acquisition for the majority of experiments that will be conducted at the ASR. ARL recommended this distribution at the N/CC on 13 May and it was generally agreed that it was a good idea. Consequently, GD/E agreed to prepare a new proposal of detailed element spacing in accordance with the ARL recommendation. Since then GD/E has prepared the proposal, and it is felt that their newly proposed spacing (minutes of 18 June N/CC) provides optimum data acquisition possible within the mechanical constraints.

3. Shorebased Data Reduction

Three functions of shorebased data reduction have been studied thoroughly during this report period. They are:

1) data filtering
2) time-of-arrival detection
3) intensity averaging.

GD/E described a proposed method for performing these three functions in GD/E Technical Report (TR)-13, pp. 42-48. At the N/CC of 19-20 March 1970, ARL personnel discussed this proposal with GD/E to obtain more detailed information than was provided in TR-13. Consequently, this proposed method was analyzed to determine its efficiency. Appendix A describes this analysis including a detailed discussion of all the material presented in this section.

Subsequent to the analysis mentioned previously, a modification to the proposed method of data filtering was suggested to GD/E at the N/CC on 14-15 April. GD/E agreed that this modification

was necessary. However, both GD/E and ARL soon discovered that this modification had impact upon time-of-arrival detection (TOAD) and intensity averaging. As a result, GD/E proposed a different method of performing these three functions at the N/CC on 13-14 May. At that time, ARL pointed out two problems that existed with this new method and GD/E agreed to examine these problems and report at the next N/CC on 17 June. At that meeting GD/E proposed another method of data reduction that resolved both problems alluded to at the meeting in May, but eliminated the possibility of performing data reduction in real-time. This new method required that the data be passed through the computer twice before the intensity averaging was completed. Although ARL felt that this latest method would provide better results than previous proposals, the fact that data reduction could not be completed in real-time was undesirable. A new method that would allow completion of intensity averaging in real-time and might provide good results was suggested to GD/E in a telephone conversation between R. Rolleigh of ARL and E. M. Smith of GD/E on 25 June. Mr. Smith agreed to examine this suggestion and comment on it at the next N/CC on 4-5 August 1970.

4. Sound Absorbent Coatings

At the 20 March 1970 N/CC, GD/E requested that ARL review data on sound absorbent coatings and provide any available information on this subject. ARL subsequently consulted with people who were working in this area and conducted a literature survey. As a result GD/E was provided with two reports that discussed this subject.

APPENDIX A

ANALYSIS re SHOREBASED DATA REDUCTION

Figures 2 and 3 of GD/E TR-13 describe the originally proposed method of performing noise bandwidth reduction filtering, time-of-arrival detection, and intensity averaging. To aid in the present discussion, these drawings are reproduced as Figs. A-1 and A-2.

The filter shown in Fig. A-1 is essentially a Fourier transform. If the frequency of interest is f, then the "in-phase replica" from the computer is sin $2\pi ft$ and the "quadrature replica" is cos $2\pi ft$. The mathematical operations performed by this filter can be written as:

$$\text{output} = \int_{t_o}^{t_o + 0.6\ \text{msec}} e^{i2\pi ft}\, S(t)dt$$

$$= \int_{-\infty}^{+\infty} w(t,t_o,T)\, e^{i2\pi ft}\, S(t)dt \quad , \tag{1}$$

where S(t) = signal being filtered.

$$\begin{aligned} w(t,t_o,T) &= 1 \quad t_o \leq t \leq t_o + T \quad , \\ &= 0 \quad t < t_o \quad , \\ &= 0 \quad t > t_o + T \quad , \text{ and} \end{aligned} \tag{2}$$

$$T = 0.6\ \text{msec} \quad .$$

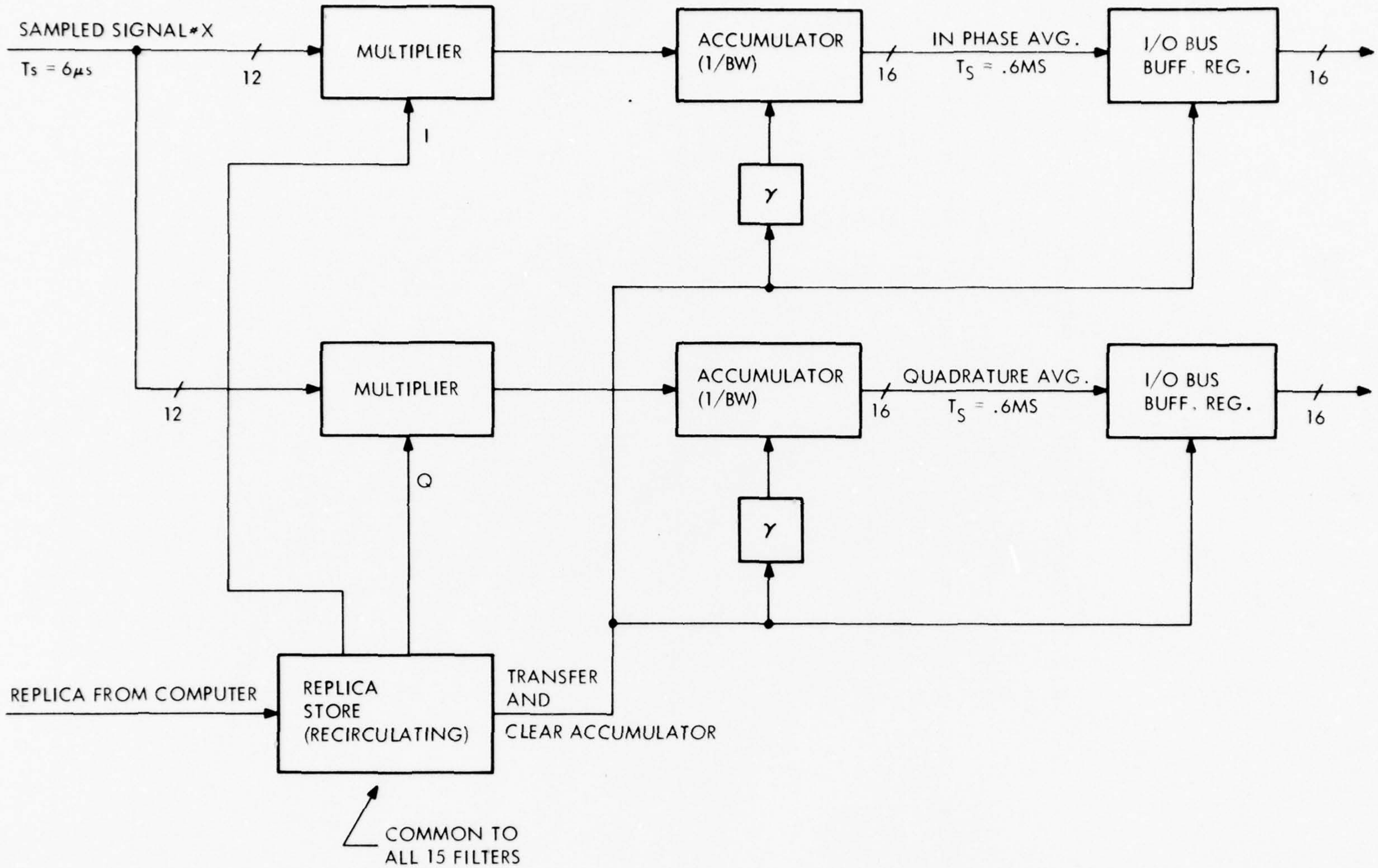


FIGURE A-1
BLOCK DIAGRAM OF SAMPLED TRANSVERSAL FILTER WITH INTERMEDIATE INTENSITY AVERAGER

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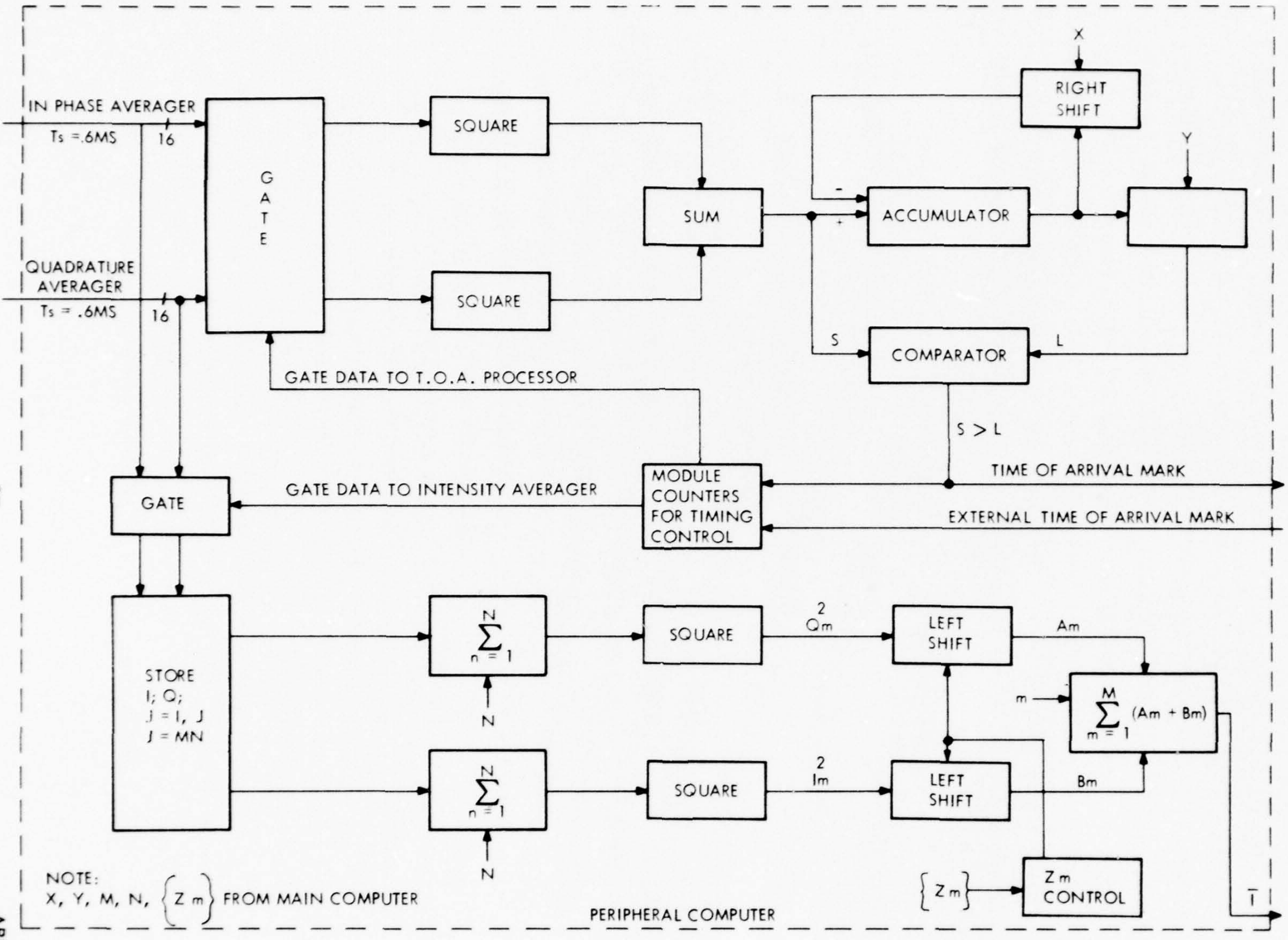

FIGURE A-2
BLOCK DIAGRAM OF TIME-OF-ARRIVAL PROCESSOR AND INTENSITY AVERAGER

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Equation 1 shows that the output is the Fourier transform of the function $w(t,t_o,T)S(t)$. Therefore, the output of this filter is a single number which represents the Fourier amplitude of the function $2(t,t_o,T)S(t)$ at the frequency f. In this respect this filter is quite different from a conventional digital filter, which preserves the waveform and envelope of the signal in which one is interested. However, this Fourier transform (FT) technique can be visualized as a type of filter and will be referred to as a filter in the following paragraphs.

From the properties of the Fourier transform, Eq. 1 can be written:

$$\text{output} = Y(f) = \int_{-\infty}^{+\infty} \tilde{w}(f_1)\tilde{S}(f-f_1)df_1 \quad , \qquad (3)$$

where $\tilde{w}(f)$ and $\tilde{S}(f)$ are the Fourier transforms of $w(t)$ and $S(t)$ respectively. Since the Fourier transform of a function of time is the frequency spectrum of that function, Eq. 4 shows that the frequency response of the filter is given by the frequency spectrum of $w(t)$. The function $w(t)$ is called the data window, and it can be seen that the choice of the data window has a significant effect on the frequency response of the filter. The data window given by Eq. 2 is called a rectangular window and is the window proposed in TR-13. Although the rectangular window is the simplest window, it provides one of the worst frequency responses. Figures A-3, A-4, and A-5 are plots of the frequency response of the filter (described in TR-13) for three values of the parameter T. These three plots show two things: (1) the longer one makes T, the better the filter rejects unwanted frequencies; (2) the longer T is, the narrower is the flat portion of the frequency response. The frequency response of the filter should be flat to within ±1/2 dB for at least 50 cycles because the signal

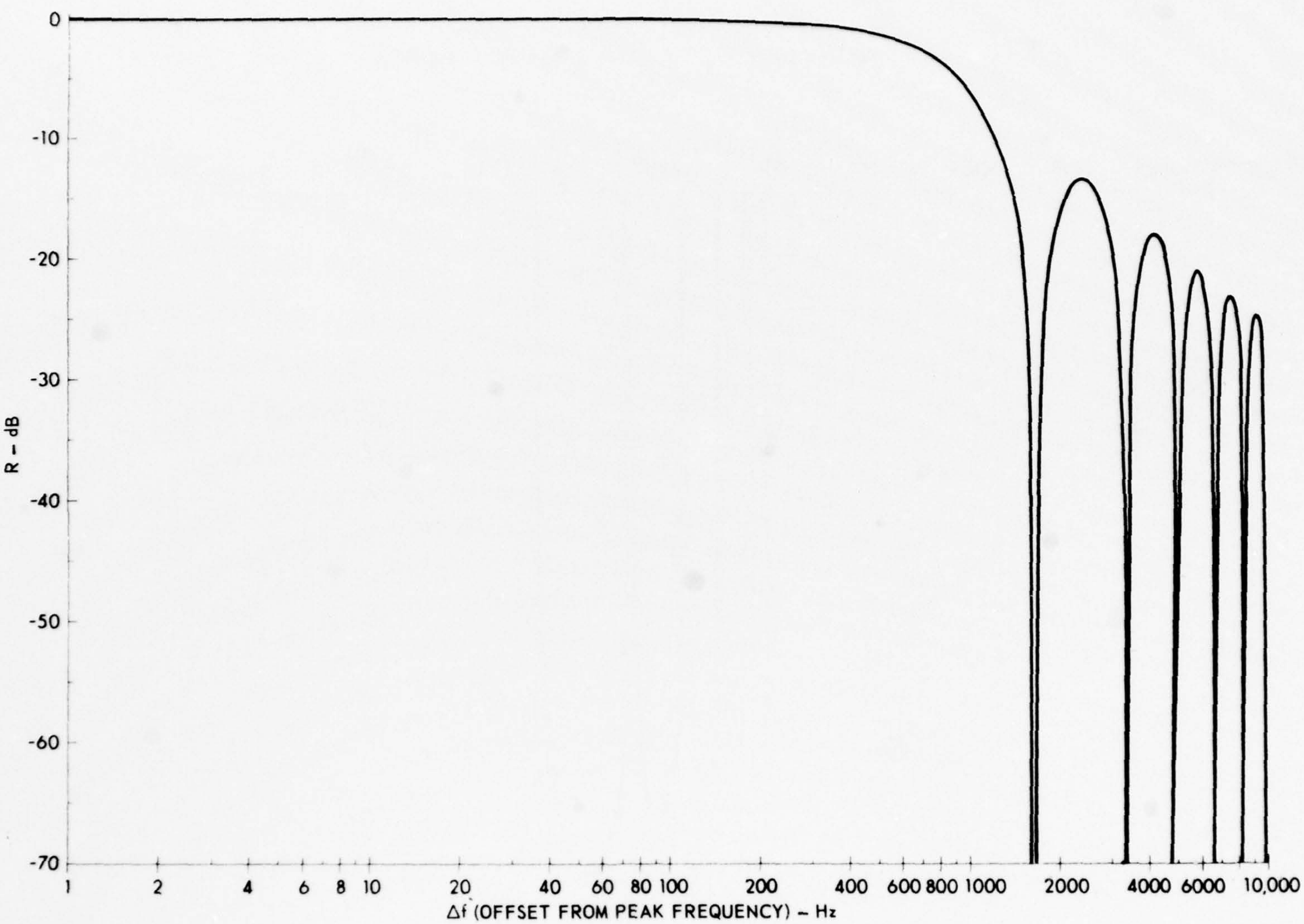

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FIGURE A-3
FREQUENCY RESPONSE (R) OF FILTER WITH RECTANGULAR WINDOW AND INTEGRATION TIME OF 0.6 msec

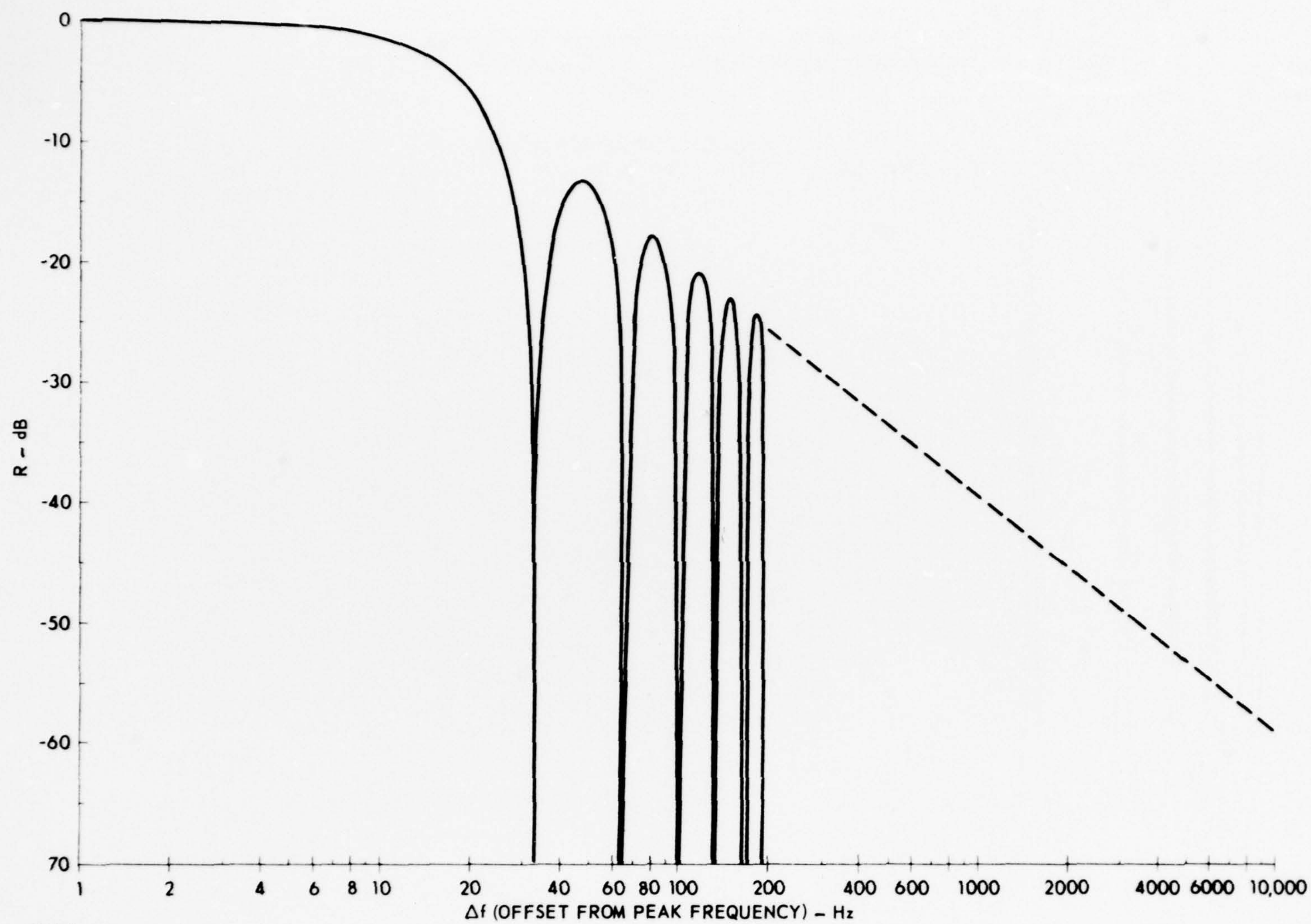

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FIGURE A-4
FREQUENCY RESPONSE (R) OF FILTER WITH RECTANGULAR WINDOW AND INTEGRATION TIME OF 30.0 msec

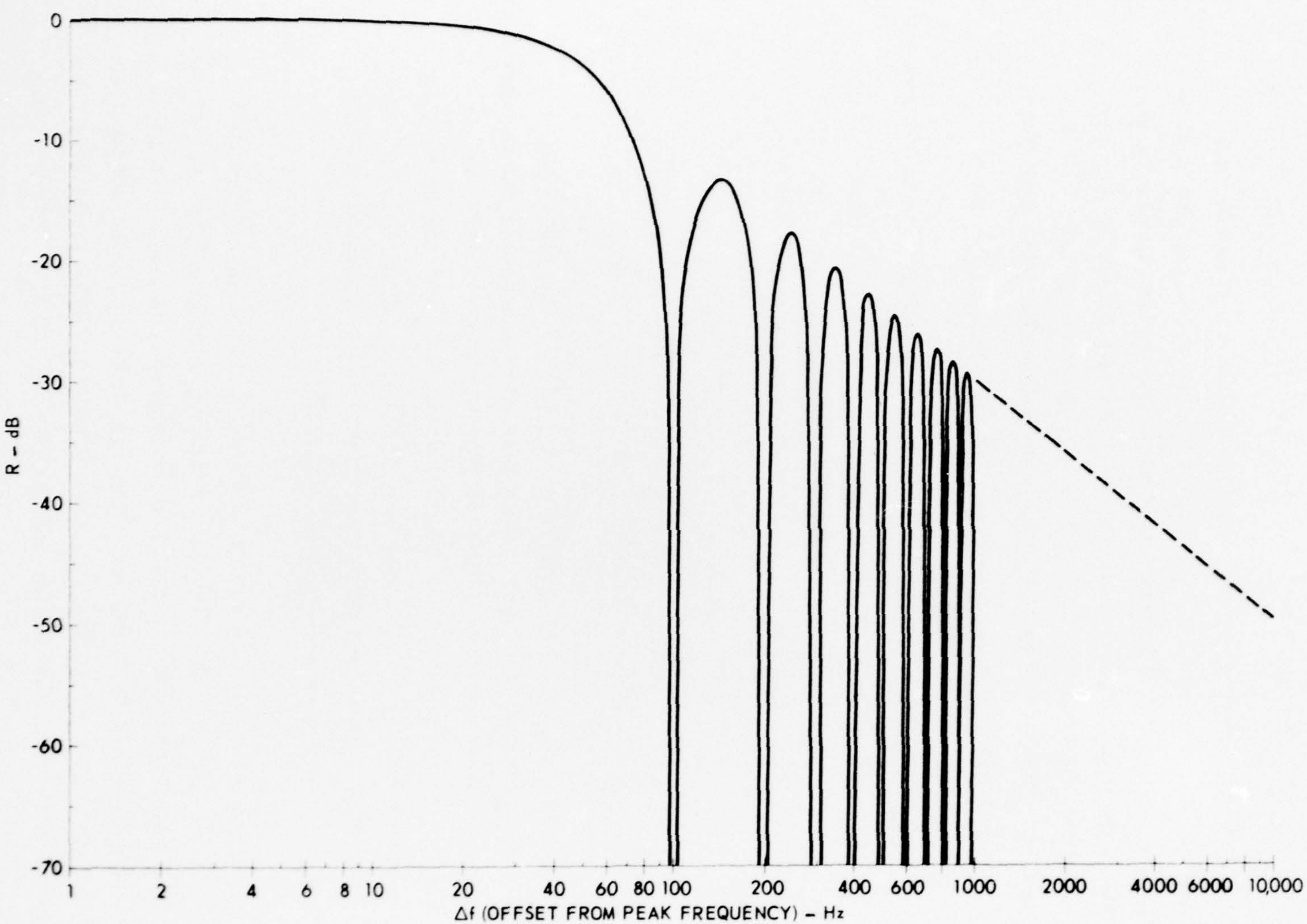

FIGURE A-5
FREQUENCY RESPONSE (R) OF FILTER WITH RECTANGULAR
WINDOW AND INTEGRATION TIME OF 10.0 msec

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at the vertical array hydrophone may be shifted in frequency due to Doppler shift. Furthermore, if this system is to be used to analyze harmonics that are 60 dB below the fundamental sonar signal, it must provide some 80 dB rejection of signals that are less than 3.5 kHz removed from the center frequency. It is clear from Figs. A-3, A-4, A-5 that no choice of T will provide a response that will meet both of these requirements.

The Tukey window given by Eq. 4 provides much superior performance.

$$
\begin{aligned}
w(A) &= \frac{1}{2}\left(1-\cos\frac{2\pi t}{T}\right) \qquad t_o \leq t \leq t_o + T \quad , \\
&= 0 \qquad t < t_o \quad , \qquad\qquad (4) \\
&= 0 \qquad t > t_o + T \quad .
\end{aligned}
$$

Figure A-6 is a plot of the frequency response of the filter using the Tukey window for T=10 msec. This plot shows that this data window provides a frequency response that is both flat over a wider region and has better rejection of unwanted frequencies. The use of a Tukey window was recommended to G. Demuth of GD/E at the N/CC on 14-15 April 1970. At that time it was agreed that some window (probably a Tukey window) other than rectangular would be used.

However, ARL and GD/E soon discovered that the use of any data window other than rectangular would seriously influence the rest of the data reduction system. The problem is that the time-of-arrival detector (TOAD) has a timing error that is equal to T, the integration time of the filter (the same T in Eqs. 2 and 4). This is because the TOAD must wait until the filter integration is complete before it has

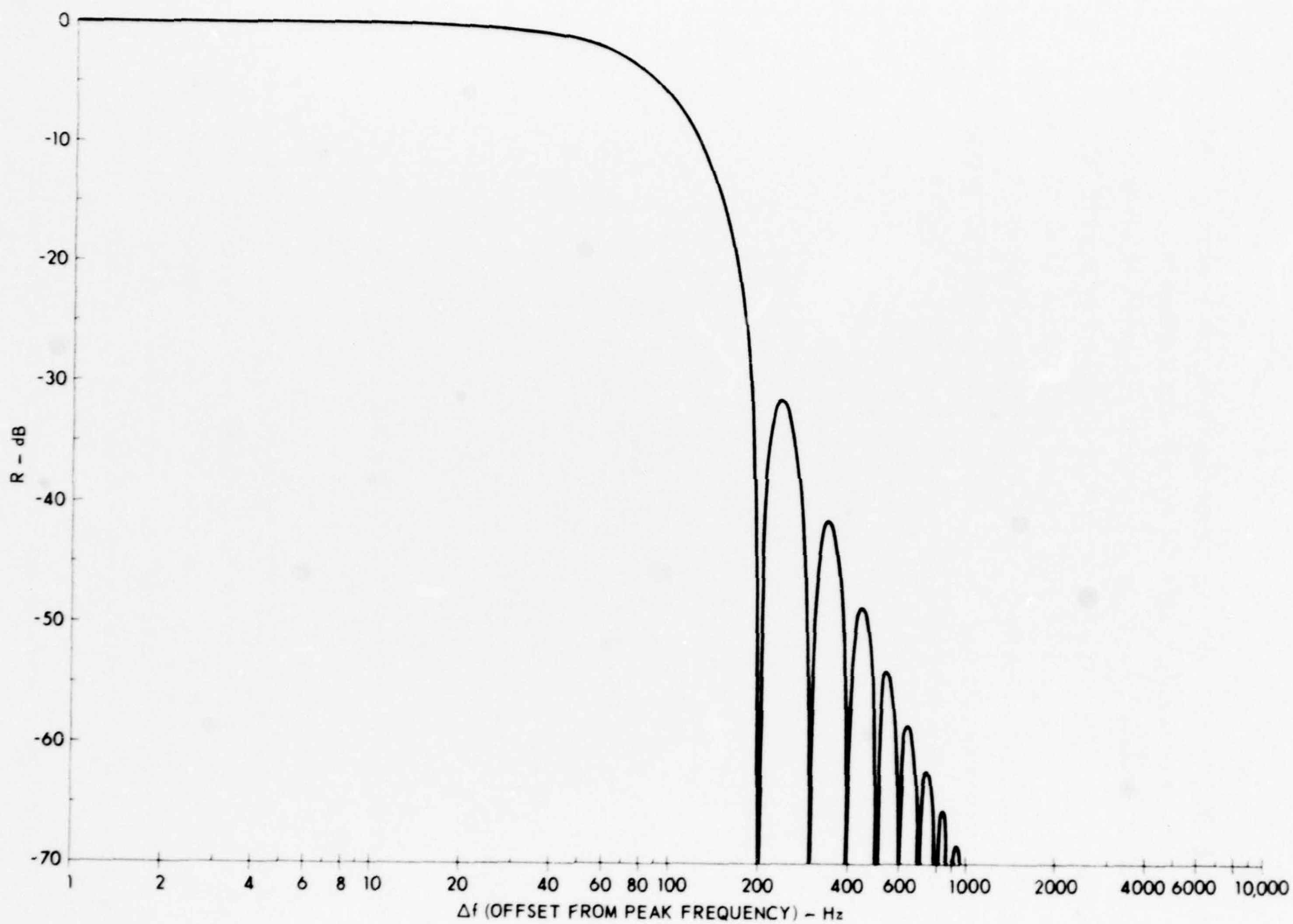

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FIGURE A-6
FREQUENCY RESPONSE (R) OF FILTER WITH TUKEY WINDOW
AND INTEGRATION TIME OF 10.0 msec

a number to examine to decide if time-of-arrival has occurred. From Fig. A-6 it is obvious that when analyzing some harmonics, T must be about 10 msec to provide the desired rejection of unwanted frequencies. It is undesirable to have time-of-arrival errors of this magnitude for processing signals that have only a 10 to 50 msec duration. This problem did not occur when using rectangular windows because, as discussed on page 44 of TR-13, it is possible to extend the integration time after time of arrival detection by summing sequential outputs of the filter. This is because

$$\int_{t_o}^{t_o+T} e^{i2\pi ft}\, S(t)dt + \int_{t_o+T}^{t_o+2T} e^{i2\pi ft}\, S(t)dt \quad ,$$

$$+ \ldots + \int_{t_o+(N-1)T}^{t_o+NT} e^{i2\pi ft}\, S(t)dt \quad ,$$

$$= \int_{t_o}^{t_o+NT} e^{i2\pi ft}\, S(t)dt \quad .$$

A similar relationship does not exist for any window other than rectangular.

At the N/CC of 13-14 May 1970, GD/E proposed to ignore this problem. They suggested that a Tukey window with integration time selected from 0.6 to 14.4 msec be used in the noise bandwidth reduction filter. This meant that the portion of the signal envelope that was used to perform the intensity average would vary in position within the envelope as much as 14 msec from ping to ping. It was pointed out by ARL that this variation was undesirable since the goal of the

experimenter in any experiment is to control as many variables as possible. It was further pointed out by ARL that the 16-bit accumulator shown in Fig. A-1 might not provide sufficient resolution for a 14.4 msec integration time. GD/E acknowledged that they had not analyzed the resolution requirement placed on this accumulator by such an extended integration time. They stated that this would be done before the next N/CC set for 17-18 June 1970.

At the N/CC of 17-18 June 1970, GD/E proposed a new method of data reduction that resolved both problems mentioned in the preceding paragraph, but introduced a new problem. The new problem was that the data must be run through the processing computer twice to complete the intensity averaging. On the first run, a 0.6 msec rectangular window would be used and the fundamental frequency of the sonar would be the center frequency of the filter. The output of the filter would be used by the TOAD to determine TOA, and a mark would be made on the data tape to locate the TOA. Then the tape would be rewound and played back into the filter a second time, with the filter using a Tukey window of any desired length that began at the TOA. On this second data run, double precision arithmetic would be used to provide the required resolution. Thus, TOA would be determined to within 0.6 msec and any desirable integration time could be chosen. However, this method eliminates on-line data reduction and, therefore, possibly increases time-on-range. ARL judges this method an improvement over all previous methods, although it is felt that there is still room for more improvement.

In a telephone call on 25 June 1970, ARL recommended to GD/E a method that might allow the data reduction to be accomplished in real-time. The system would be identical to that shown in Fig. A-1 and A-2 except that the REPLICA STORE shown in Fig. A-1 would be

neither recirculating nor common to all 15 filters. It should be noted that this modification was also required in the proposal made by GD/E on 17 June 1970. A 0.6 msec rectangular window with the filter center frequency equal to the fundamental frequency of the sonar would be used until the TOA was detected. When the TOA mark is produced by the TOAD, the computer substitutes a new replica given by Eq. 5,

$$\begin{aligned} \text{in-phase replica} &= (\sin 2\pi ft)\left[\frac{1}{2}\left(1-\cos\frac{2\pi t}{T}\right)\right] \quad , \\ \text{quadrature replica} &= (\cos 2\pi ft)\left[\frac{1}{2}\left(1-\cos\frac{2\pi t}{T}\right)\right] \quad , \end{aligned} \tag{5}$$

with T = integration time (any desired length up to about 50 msec)

t = 0 when TOA mark occurs and increases linearly with time after that, and

f = frequency of interest (possibly a harmonic of the sonar fundamental frequency).

This replica would provide a Tukey window of any desired integration time. The error in TOA detection would be only 0.6 msec and the data would be completely processed in real-time, thus eliminating the need for running the data through the computer a second time as in the GD/E proposal of 17 June. The accumulator shown in Fig. A-1 would accept only 100 samples before it is cleared, thus eliminating the need for double precision in those accumulators. The outputs of these accumulators could be stored as shown in the lower half of Fig. A-2; during the dead portion of the ping cycle, sequential outputs could be summed by using double precision, thus reconstructing the entire Tukey window before intensity averaging. Therefore, the intensity average for each ping would be output before the next ping arrived. GD/E personnel stated that they would consider this recommendation and would comment on it at the next N/CC of 4-5 August.

In conclusion, it is felt that all of the methods described previously are inferior to conventional digital filtering of the original signal for two reasons:

1) If conventional filtering were used, there would be no error in TOA, and the TOA could be set according to the envelope of the frequency of interest. If the FT methods described previously are used, one must always set the TOA according to the fundamental frequency, even when one is interested in some higher harmonic.

2) Conventional filtering techniques would provide any desired frequency response, whereas the FT methods described previously provide only a limited number of frequency responses.

However, conventional digital filtering requires 20 to 40 machine operations per input data sample. The FT methods described previously require only 4 operations per data sample, thus representing a significant hardware savings. Since the FT methods described in this report appear adequate for most ASR applications, it is probably more cost-effective to use one of these methods rather than the more expensive and sophisticated conventional digital filtering.

APPENDIX B

TECHNICAL PERSONNEL ASSIGNED TO CONTRACT N00024-70-C-1117

Name	Approximate Fraction of Time Assigned	Title
D. D. Baker	0.7	Head, Electroacoustics Division
J. E. Stockton	0.1	Section Supervisor
D. A. Smith	0.4	Section Supervisor
J. J. Truchard	0.75	Section Supervisor
R. L. Batey	0.2	Section Supervisor
E. Blum	1.0	Section Supervisor
K. W. Alkier	0.25	Technical Staff Assistant
G. C. Badke*		
F. C. Houston*		
W. P. Lawson	0.6	Technical Staff Assistant
B. O. Moses*		
P. R. Mongrain	1.0	Technical Staff Assistant
M. Nokes*		
R. L. Rolleigh	1.0	Research Scientist Associate
V. D. Scott	0.5	Research Scientist Associate
B. S. Shaw	0.2	Research Engineer Associate
J. L. Shorey	1.0	Research Scientist Associate

*Part-time student employment

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3 August 1970

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7	J. J. Truchard, ARL/UT
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13. ABSTRACT

This report summarizes the technical work accomplished under Contract N00024-70-C-1117 during the period 1 April through 30 June 1970. ARL has continued to assist and support NAVSHIPS by completing tests on an AN/SQS-31 sonar dome, completing tests on an AN/SQS-43 TR-194 transducer, and completing the marine railway for loading 30-ton transducers aboard the STEP barge. Under subcontract with ARL, Stanford Research Institute has contributed significantly to the work by writing a proposed repair procedure for AN/SQS-26BX transducer elements, by participating with ARL in the survey of WESTPAC transducer installation activities, and by continuing to serve as the STEP Working Group's coordinator for the Mare Island Transducer Repair Facility (TRF). ARL personnel have continued to assist the Navy Underwater Sound Laboratory with monitoring the development of the AUTEC Sonar Range; ARL is primarily concerned with monitoring the data acquisition system development. (U-FOUO)

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Sonar Transducer Evaluation						
STEP Barge Facility						
High-Level Impedance Measurements						
Transducer Repair Facilities						
Transducer Testing at Naval Shipyards						
AUTEC Sonar Range						
Sonar Calibration						

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